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The views, opinions and/or findings contained in this report are those of the author(s) and should not contrued as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT
Microscopic organisms control ocean processes at global scales. However, the lives of these organisms are governed by specific and unique microscale physical processes that were long over-looked by oceanographers. The focus of the proposed meeting will be on the physics underlying the biological and ecological interactions among microscopic marine biota. The fundamental rationale underpinning this meeting is that the study of the microscale

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as of 25-Aug-2017

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MICROSCALE OCEAN BIOPHYSICS
Sunday Jan 11 – Friday Jan 16, 2014
Aspen Center for Physics

Invited talks: 30 min + 15 min of questions
Contributed talks: 15 min + 5 min of questions

SUNDAY JAN 11

5 – 7 pm: **REGISTRATION & RECEPTION**: come meet everyone to kick off the week!

MONDAY JAN 12

8 am Kickoff lecture: **Thomas Kiørboe** (Technical University of Denmark): "Microscale Ocean Biophysics"

8.15 am Invited introductory lecture: **Stuart Humphries** (U Lincoln): "Looks matter: The function of bacterial shape"

9.00 am Coffee break

9.30 am **SESSION 1: "Sensing, signaling and chemical exchange" (part 1)**

9.30 – Invited lecture: **Mark Hay** (Georgia Tech): "Ecosystem tipping points, chemical ecology and the death spiral of coral reefs"

10.15 – **Jean-Baptiste Raina** (U Technology Sydney) "Linking the composition of phytoplankton chemical signatures with bacterial behavioral responses at the microscale"

10.40 – 4 pm **Free time** for social and winter activities

4 – 4.30 pm Afternoon coffee break

4.30 – 6 pm **1-SLIDE SELF-INTRODUCTION SESSION**
1-slide, 1-minute self-introduction by each participant
Please send your 1 slide to Justin.Seymour@uts.edu.au before Jan 5

6 – 7.30 pm **INTERACTIVE POSTER SESSION (with beers) – GROUP 1**
Posters can be put up on Sunday night and left in place until Tuesday night

7.45 pm **GROUP DINNER** (at the Meadows; paid for).

TUESDAY JAN 13

8 am **SESSION 1: "Sensing, signaling and chemical exchange" (part 2)**

8.00 – Invited lecture: **Benjamin van Mooy** (WHOI) "Field observations of intersections between infochemicals, microbial interactions and biogeochemical fluxes in the ocean"

8.45 – **Ottavio Croze** (U Cambridge) "Algal bacterial interactions at a distance"

9.10 – Coffee break

9.40 – Invited lecture: **Rachel Foster** (Stockholm U) "Metabolic Interactions between diatoms and cyanobacteria in the open ocean."

10.30 – 4 pm **Free time** for social and winter activities

4 – 4.30 pm Afternoon coffee break

4.30 pm **SESSION 2: "Particles - ONE"**

4.30 – Invited lecture: **Gabriel Juarez** (MIT) "Biophysics of particle and oil degradation by marine bacteria: A microscale perspective"

5.15 –**Evan Variano** (UC Berkeley) "Tumble vs. spin: How particle shape affects the rotational response to turbulence"

5.40 – 7 pm **GRAPHICAL COMMUNICATION WORKSHOP**
Invited lecture with group discussion: **Glynn Gorick** (Graphic artist, UK)

7 pm Dinner (on your own). Suggestion from the Aspen Center for Physics: the restaurants Asie ($$) and Mezzaluna ($$$) will seat meeting attendees together and offer an appetizer for the table.

WEDNESDAY JAN 14

8 am **SESSION 3: "Diffusion and encounters"**

8.00 – Invited lecture: **Colin Stedmon** (Technical University of Denmark) "Why does dissolved organic matter persist in the deep ocean: Is the solution dilution?"

8.45 – **Kwangmin Son** (MIT) "Live imaging of viral encounter and adsorption dynamics"

9.05 – **Michael Echevarria** (U North Carolina) "Feast or flee: Mechanistic basis of predator evasion and prey capture behaviors in the microzooplankton *Favella* sp."

9.25 – Coffee break

10.00 – **Katherine Allison Smith** (U Washington) "Group behavior of bacteria to produce exoenzymes linked to diffusion in a model of sinking"

10.20 – **Janna Nawroth** (Harvard U) "Controlled biofilm formation in a marine ciliated organism"

10.40 – 4 pm **Free time** for social and winter activities

4.30 pm **PHYSICS CAFÉ: Mimi Koehl (UC Berkeley) and Lee Karp-Boss (U Maine)**
Wheeler Opera House

5.30 pm **PUBLIC LECTURE: Mark Denny (Stanford)**
"How plants and animals survive crashing ocean waves"
Introduction by **Thomas Kiørboe**
Wheeler Opera House

7 pm Dinner (on your own). Suggestion from the Aspen Center for Physics: the restaurants El Rincon ($$) and Campo de Fiori ($$$) will seat meeting attendees together and offer an appetizer for the table.

THURSDAY JAN 15

8 – 10.30 am **SESSION 4: "Particles - TWO"**

8.00 – **I**nvited lecture: **Pete Jumars** (U Maine) "Models and muddles in hydrosol filtration"

8.30 – Invited lecture: **Curtis Deutsch** (U Washington) "A mechanistic model of particle flux applied to the global ocean"

9.15 – Coffee Break

9.45 – **Brian White** (U North Carolina) "Retention of marine aggregates at sharp density transition: Layer formation"

10.05 – **Ksenia Guseva** (U Oldenburg) "Influence of the history force on inertial particle advection"

10.30 – 4 pm **Free time** for social and winter activities

4 – 4.30 pm Afternoon coffee break

4.30 – 6 pm **GROUP DISCUSSION – topic TBD**

6 – 7.30 pm **INTERACTIVE POSTER SESSION (with beers) – GROUP 2**
Posters can be put up on Wednesday morning and left in place until Friday morning

7.45 pm **GROUP DINNER** (at the Meadows; paid for).

FRIDAY JAN 16

8 am **GROUP REPORTS FROM DISCUSSION**

8.30 am **SESSION 5: "Propulsion and organism-generated flows"**

8.30 – **Bryce Inman** (UCSD) "Small swimmers mix the microscale environment by deforming gradients and enhancing diffusive flux"

8.50 – **Jackson Sage** (U Lincoln) "Adaptation to temperature in *Tetraselmis* swimming has two rates"

9.10 **–** **Manu Prakash** (Stanford) "The deadly swimming of *Cercariae*: An unusual Stokesian micro-swimmer"

9.30 – **Monica Martinez** (Caltech) "Fluid transport by planktonic aggregations"

9.50 – **Victor China** (Tel Aviv University) "Hydrodynamic regime dictates feeding performance and strike kinematics during the 'critical period' of larval fishes"

10.10 **–** Coffee break

10.40 am **SESSION 6: "Plankton and turbulence"**

10.40 – **François-Gaël Michalec** (ETH) "Swimming dynamics of Calanoid copepods in turbulent flow"

11:00 – **Jeanette Wheeler** (WHOI) "Isolating the hydrodynamic triggers of the dive response in eastern oyster larvae"

11.20 am **GROUP PLANNING OF "MICROSCALE OCEAN BIOPHYSICS 4.0"**

12 noon Meeting adjourns

CONFERENCE AND SYMPOSIA GRANTS
"Microscale Ocean Biophysics"
Aspen Center for Physics, Jan 11-16, 2015

4. Technical Proposal Preparation.

This technical proposal requests support for a scientific meeting entitled ***"Microscale Ocean Biophysics"*** to be held at the Aspen Center for Physics in January 2015.

(a) Summary

Microscopic organisms control ocean processes at global scales. However, the lives of these organisms are governed by specific and unique microscale physical processes that were long over-looked by oceanographers. The focus of the proposed meeting will be on the physics underlying the biological and ecological interactions among microscopic marine biota. The fundamental rationale underpinning this meeting is that the study of the microscale dynamics of the ocean will significantly benefit from a stronger input by physicists, and will present physicists with a new set of problems in need of quantitative tools and mechanistic thinking. This will require a new focus on small-scale fluid physics, mass transport, active suspensions, turbulence, and mechanics in general. Application and advancement of these topics in the context of oceanographic processes will greatly improve our understanding of how organism life is constrained and has evolved to exploit the fundamental laws of physics. Importantly, the physical processes considered in the proposed meeting have relevance and implications that extend far beyond ocean ecology and several of the topics that will be covered have direct significance to defence science and technology. This includes biofouling, microrobotics, and acoustics and thin layers in the ocean.

Scientific Background for Meeting Topic: The activity and behavior of microbes dominate biogeochemical cycling and productivity in aquatic systems. More than 99% of the biological processes in the ocean take place within an invisible microscopic world to which we have limited access and which is radically different from the macroscopic terrestrial world where we have developed our intuition. Over the past two decades, there has been a growing realization that the ecology of marine microorganisms depends not only on the bulk environmental conditions, but also crucially on small-scale biophysical interactions and microscale heterogeneity in physical and chemical conditions.

It is becoming clear that physical processes play a fundamental role in shaping the microscale landscapes that form the arena in which most marine organisms forage, reproduce and encounter each other. Diffusion governs nutrient uptake of osmotrophic organisms, flow and movement determine encounter rates, advection and turbulence shape chemical signatures and the ways that these are sensed by organisms. Motility and the physics of propulsion acquire a particular significance as a means to navigate this patchy seascape and is itself affected by fluid flow. The small scale further implies that many of these processes occur at low Reynolds numbers, and thus unfold in a physical regime that often defies intuition. The result is a rich

landscape of opportunities for physicists, mathematicians and engineers to be involved in oceanographic and environmental problems, and for oceanographers to inspire and utilize physical concepts and approaches more pervasively.

(b) The topics to be covered.
A decade ago, an article in Nature launched this call: "*it is time for oceanographers to embark in a bold exploration of the oceans, this time at the millimeter scale*" (Azam & Long, 2001). Over this past decade, it has become clear that an absolutely fundamental ingredient in this microscale exploration is the understanding of microscale physical processes. Progress will thus depend on a renewed focus on the physical microenvironment of single organisms as the fundamental unit of investigation and on the development of new experimental tools for studies at the microscale and of appropriate mathematical modeling approaches. This focused meeting will be an important step in fostering the pursuit of this new vision. Within this framework, the key topics covered during the meeting will include:

• Diffusion dynamics of solutes and organisms within ocean ecosystems
• The influence of small-scale turbulence and advection on organism and substrate transport and distributions
• Organismal sensing of microscale physical and chemical features of the marine environment
• Foraging behaviours and strategies of organisms within a heterogeneous seascape
• The interaction of fluid flow and organism movement and the effects on encounter rates
• The physics of propulsion at small scales
• The mass transport and filtration processes involved in filter feeding by marine organisms
• The ecological role of chemical signaling between marine organisms
• Physical flows generated by marine organisms
• New tools and techniques for studying microscale physical, chemical and biological processes

(c) The location and dates:
We have been granted a 5-day meeting time-slot at the Aspen Center for Physics between 11 and 16 January 2015. This follows the first of these meetings, which was held at the same location in 2011 and a follow up meeting held at the School of Physics at Les Houches (France) in 2013.

(d) How the conference relates to Army interests
As described above, several of the topics covered during the proposed meeting have significance that extends beyond their importance to ocean ecology, with many having direct pertinence to army interests. Microscale physical, chemical and biological processes underpin a range of natural phenomena that can strongly influence, impede or enable military activities, and are also fundamentally relevant to the development of defense technology. Topics covered at our meeting that will have direct or indirect scientific relevance to army interests include, but are not limited to:

Modeling the physical processes involved in the dispersion of chemicals and microorganisms: The dispersal of chemicals and microorganisms by diffusion and the spread and mixing of organisms and solutes by turbulence will be a key thematic focus of the meeting. The same physical dynamics that so greatly influence the ecology of marine organisms will be fundamental parameters in the dispersal dynamics of biological agents and chemical weapons in both aquatic and atmospheric settings. As such, new quantitative insights into these physical processes will aid efforts to model and predict these processes under different scenarios, which will enhance the ability to detect and respond to the use of chemical or biological weapons by an enemy.

Propulsion at small-scales: As described above, physical processes at the microscale are fundamentally different to those occurring at the macroscale. This is particularly true when considering the forces effecting the propulsion and movement of organisms through a low Reynolds number, microscopic environment. These conditions need to be considered when designing micro- or nano-robots for military applications, because these robots will require methods of mechanical propulsion that are suitable for microscale physical conditions. Microscopic organisms have evolved an amazing array of ingenious strategies that allow for effective movement under these conditions and from a micro and nano-engineering perspective, there is much to be learnt from these natural design features.

Biofouling of vessels and aquatic equipment: Biofouling involves the accumulation of microorganisms, plants and animals on submerged surfaces in aquatic environments and is again an intrinsically microscale biophysical process. Biofouling on vessels, underwater sensors and equipment within marine settings causes a number of negative implications. Hull fouling on vessels increases drag, which increases fuel consumption and can amplify the acoustic signature of the vessel. These effects lead to clear economic and strategic burdens. Gaining a microscale understanding of the ecology and physics of natural biofouling is both a topic that will be covered at our meeting and an area that will enhance capacity to prevent the negative implications of biofouling in military and non-military settings.

Acoustic effects of plankton thin layers in aquatic systems: Due to their huge abundance in the water column, planktonic organisms and other suspended organic materials fundamentally influence the physical properties of seawater. Importantly, these plankton are distributed heterogeneously at small spatial scales, with dense “layers” of these organisms commonly occurring in the ocean. These layers can significantly alter the acoustic properties of seawater, which has significance for the accuracy of acoustic sensing and sonar. Gaining a more precise understanding of both the biophysical processes that drive the formation of these plankton layers and the physical consequences of layer formation will greatly aid in the development of more accurate acoustic sensing and detection capabilities for use in aquatic settings.

Bioluminescence and its physical drivers: Many planktonic organisms exhibit bioluminescence, a property characterized by the production and emission of light by cells. It has been recognized that physical disturbance (turbulence) is a key mechanism in the expression of bioluminescence, and that a manifestation of this response can be the illumination of seawater as vessels pass through a patch of bioluminescent plankton. The strategic exploitation of this natural phenomenon will aid in the detection of both surface and sub-surface vessels. Hence, a better understanding of the biophysical drivers of bioluminescence will enhance the capacity of the military to both detect enemies and evade detection within aquatic settings. Recently, efforts have also been made to exploit bioluminescence within terrestrial settings (http://www.armytimes.com/article/20100911), whereby natural bioluminescence could be used to mark objects or sites in a manner that is invisible to heat-seeking technology, develop bioluminescent "friend or foe" identification markers and security systems, or to produce non-heat emitting landing zone markers for helicopters. Once again, the expression of bioluminescence by planktonic marine organisms is a microscale biophysical problem, of the type that will be covered at our meeting.

These are just a sample of the many topics to be covered at our meeting that are likely to address cutting edge scientific problems that we believe will ultimately benefit the development or improvement of army technology.

(e) Organizing Committee

The organizing committee for this meeting is composed of:
Roman Stocker (Massachusetts Institute of Technology, romans@mit.edu),
Stuart Humphries (University of Hull, S.Humphries@hull.ac.uk),
Thomas Kiørboe (Technical University of Denmark, tk@aqua.dtu.dk).
Justin Seymour (U. of Technology Sydney, Justin.Seymour@uts.edu.au)
Lee Karp-Boss (University of Maine, lee.karp-boss@maine.edu)
Biographical sketches are attached.

(f) Participants

More than 80 scientists have expressed their interest in the meeting to date. Our experience with two previous editions of this meeting indicates that attendees will include a healthy balance of faculty, postdocs and students. We seek to have funding that allows us to invite approximately 10 top speakers from across the world and contribute to defray costs of participants, in particular for junior scientistis, women, minorities and attendees from developing countries. Speakers who have so far accepted our invitation include:

Public seminar

Mark Denny (Stanford)

Invited speakers

Mimi Koehl (Berkeley)
Lee Karp-Boss (University of Maine)
Colin Steadmon (Technical University of Denmark)
Curtis Deutsch (University of Washington)

Mark Hay (Georgia Tech)
Benjamin van Mooy (WHOI)
Rachel Foster (Stockholm University)
Gabriel Juarez (MIT)

(g) Summary of how the results of the meeting will be disseminated.
Following the 2013 meeting held at the School of Physics at Les Houches (France), we were granted the opportunity to generate a "Special Theme Issue" in the leading journal *Limnology & Oceanography: Fluids and Environments.* We are currently preparing and editing this issue and our goal will be to produce a follow up, open access issue detailing the research described in the 2015 meeting within the same journal or to emulate this output in a similar highly ranked journal. Finally, a major motivation for this meeting is to catalyze new research collaborations and projects, which we expect will lead to many new results and research outputs.

(h) A signed cover page is provided.

5. Cost Proposal Preparation.

(a) Total project conference costs by major cost elements.
The workshop is expected to cost approximately 65,000$, including invited speaker costs (travel and accommodation), local expenses, and support for junior scientists (in particular women and minorities). We would like to apply for **20,000$ from ARO** in support for this meeting. No ARO provided funds will be used to support attendance, subsistence or services in connection with the workshop for any government employee.

(b) Anticipated sources of conference income and amount from each.
We currently have secured 27,000$ from an internal MIT source (MIT Hayashi Fund). There is a possibility we may obtain funding in the amount of approximately 15,000$ from the Moore Foundation (request pending).

(c) Anticipated use of funds requested.
Please see attached budget

(d) A budget is attached.